IGS LEO Pilot Project

H. Boomkamp, J. R. Dow

In comparison to ground-based tracking systems like SLR or DORIS, on-board GPS offers the important advantage of continuous tracking coverage of a low Earth orbit, without needing a complex network of tracking stations. To the LEO missions this means that GPS has become an attractive, straightforward tracking system, which is why there will be five operational low Earth orbiting satellites with a GPS receiver on board. To the IGS the LEO can form an orbiting tracking station for the GPS constellation itself that may provide information that is not available from Earth-based stations. The primary goal of the IGS LEO Pilot Project is to explore the ways in which LEO GPS data may enhance the IGS products.

The year 2001 marked the release of the first substantial LEO datasets, first from CHAMP and later from the SAC-C mission. Some initial problems with SAC-C lead to a situation where most centers concentrated on the CHAMP data. The orbital height of CHAMP varies from about 450 km just after launch to below 300 km at the end of its operational life (~2006 or later). At this low altitude a satellite is very sensitive to orbit perturbations due to high-degree gravity field harmonics - which illustrates the main mission objective - and due to atmospheric effects. Accordingly, the IGS Associate Analysis Centers that started working on the CHAMP data soon found out that precise orbit determination for such low satellites is much more difficult than it is for the GPS satellites.

Although it is not obvious what precision level is required before the LEO data can have some positive impact on the IGS products, the initial POD precision for CHAMP was around 25 cm RMS or worse, which is an order of magnitude larger than the typical precision with which Earth-based IGS station coordinates are known. It was generally considered premature to start analyzing data in IGS context from a single LEO at a precision level that must be considered incompatible with that of the IGS products. By consequence the principal interest became to improve POD quality at the centers that were working on the CHAMP data. To this purpose the CHAMP Orbit Comparison Campaign was initiated in September 2001, in which ultimately 13 different Centers participated (see Table 1). The status of the CHAMP campaign – which will continue as long as centers keep sending new contributions - can be found on the IGS LEO PP website at http://www.nng.esoc.esa.de/gps/igsleo.html.

To further assist the AACs in their efforts of processing the CHAMP data, GFZ agreed to organize a CHAMP user meeting in October 2001, which was attended by representatives of many of the participating centers, and was well received. Towards the end of the year 2001 several of the centers approached POD precision levels of around 5 cm RMS. This showed that there should no longer be fundamental difficulties in GPS-based POD for low satellites. It also became clear that several AACs had to implement substantial changes in their software before reaching the same precision levels. These initial technical difficulties have so far limited the extent to which LEO GPS data could be

analyzed for IGS purposes, but rapid progress can be noticed among the centers that participate in the LEO Pilot Project.

Table 1: Associated Analysis Centres participating in the CHAMP Orbit Campaign 2001

ASI	Agenzia Spaziale Italiana, Matera, Italy
AIUB	Astronomical Institute, University of Bern, Switzerland
CNES	Centre National d'Etudes Spatiales, Toulouse, France
CSR	Centre for Space Research, University of Texas, USA
DEOS	Delft institute for Earth Oriented Space Research, The Netherlands
ESOC	European Space Operation Centre, Darmstadt, Germany
GFZ	GeoForschungs Zentrum, Potsdam, Germany
GRGS	Groupe de Recherche de Geodesie Spatiale, Toulouse, France
JPL	Jet Propulsion Laboratory, Pasadena, USA
NCL	Newcastle University, UK
TUM	Technical University of Munich, Germany
UCAR	University Corporation for Atmospheric Research, USA
UNB	University of New Brunswick, Canada

Table 2 Highlights of IGS LEO Pilot Project

1999

- ***March*** **Potsdam workshop recommendations for starting PP**

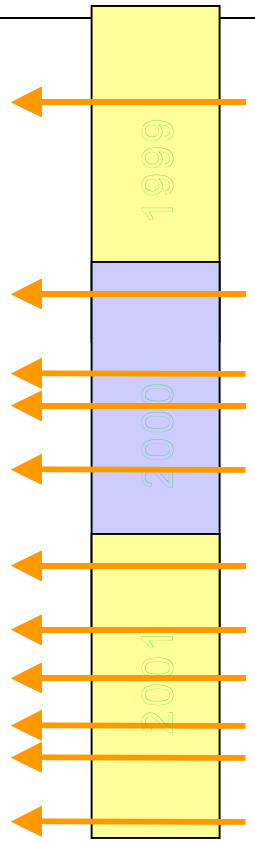
2000

- ***January*** **Call for participation IGS Mail 2669**
- ***April*** **LEO proposals deadline - 26 proposals**
- ***July*** **Launch of CHAMP**
- ***November*** **Launch of SAC-C**

2001

- ***February*** **LEO Working Group Meeting, Potsdam**
- ***May*** **Release of CHAMP data - ESOC AAC Coordinator**
- ***Summer*** **Implementation of CHAMP processing at AAC**
- ***September*** **Call for participation in CHAMP Orbit Campaign**

  Release of SAC-C data
- ***October*** **CHAMP user meeting Potsdam**
- ***December*** **First results of CHAMP campaign Launch of JASON**



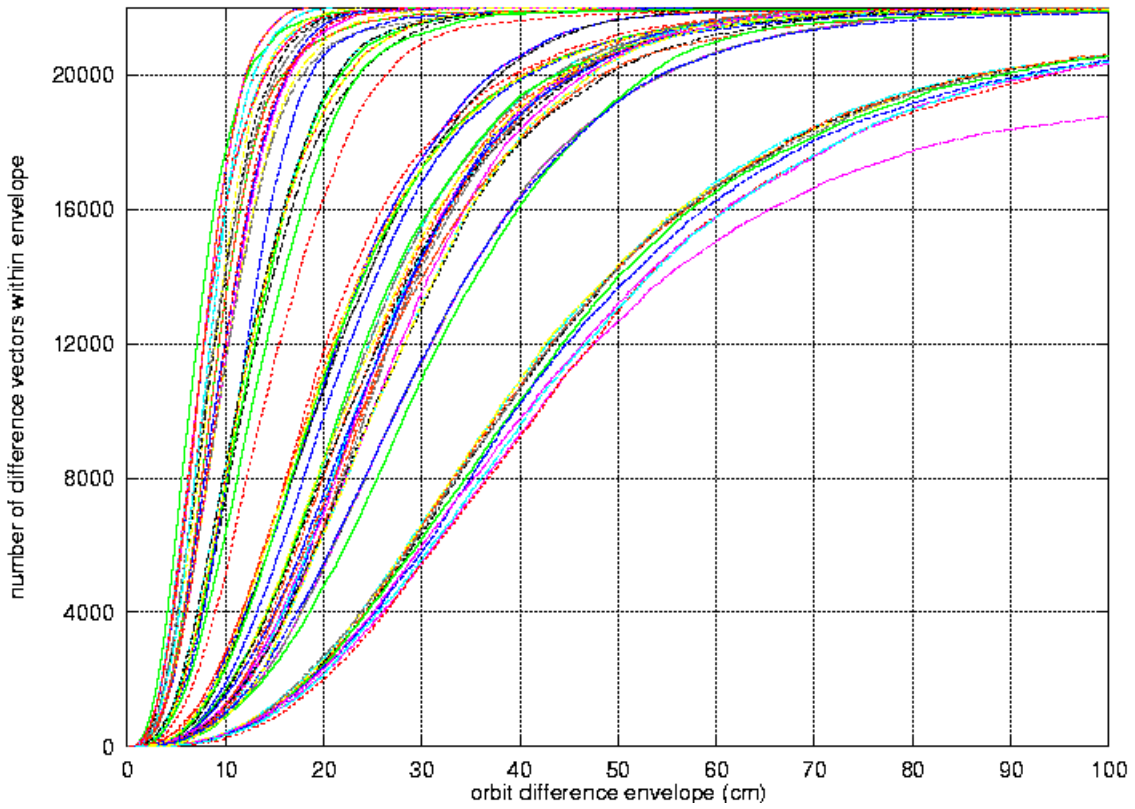


Figure 1: *CHAMP orbit difference distributions for the 78 comparisons that can be formed between 13 independent solutions. The RMS over 22000 sample points varies from 8.3 cm (top curves) to 60 cm (lowest curves).*

A different issue has been some lack of clarity about the organization of the IGS LEO Pilot Project. The IGS LEO Working Group has existed since 1999, but by May 2001, when ESOC took on the role of IGS LEO Associated Analysis Center coordinator, there had been no concrete activities within the Pilot Project (mainly because of the lack of LEO data). When the LEO data arrived and the technical difficulties were being solved, it became apparent that the maturity of LEO data processing differed widely among the participating Associate Analysis Centers. In general three categories of AACs can be identified:

- Centers that have been involved with the CHAMP or SAC-C mission from the start, and have had access to the data and satellite information since its launch: GFZ, JPL, GRGS.

- Centers that were not directly involved with the CHAMP mission but that had adequate expertise in LEO POD combined with state of the art processing systems: e.g. CSR, DEOS, TUM.

- Centers that have experience with GPS orbits and clocks, but little or no experience with LEO satellites. By the time that the data was released, these centers discovered that they need substantial changes to their processing systems to reach state of the art precision levels for CHAMP data processing.

Independent of this, a difference in emphasis can be noticed between typical LEO groups, which mainly consider the GPS data as a means for generating precise LEO products, and typical IGS (associate) analysis centers that prefer to look at the LEO data as if implementing a new IGS station.

Diversity in processing methods and diversity in emphasis among participating centers are traditionally the strengths of the IGS, but the risk of incoherency must of course be avoided. An important goal for the immediate future is therefore to focus the LEO Pilot Project on its principal objectives, and to define a clear set of long-term and short-term objectives.

A single LEO platform like CHAMP or SAC-C is valuable to implement data processing flows, but will probably not bring a notable enhancement of the routine IGS products. The launches of JASON-1 in December 2001 and the twin GRACE satellites in March 2002 ensure that there will soon be flight receiver data from five operational LEO satellites. Their number is only expected to grow in the future, and it is not unrealistic to predict that a constellation of twenty GPS LEO platforms will be reached within the second decade of this century. An entire new approach to IGS product generation may be on the horizon, but before this can be confirmed or discarded a substantial effort must be invested in LEO data analysis. The bulk of these analysis activities will take place in the two or three years to come, so that the IGS LEO Pilot Project can look forward to very interesting times.